Preventive Veterinary Medicine, 8 (1990) 191-202
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

Enrollment of Tennessee Beef Herds in the National Animal Health Monitoring System

JOHN C. NEW, JR.[1], WILLIAM L. SANDERS[2] and VICTOR C. BEAL, JR.[3]

[1]*College of Veterinary Medicine and* [2]*Agriculture Experiment Station, University of Tennessee, Knoxville, TN 37901-1071 (U.S.A.); and* [3]*U.S. Department of Agriculture, Animal-Plant Health Inspection Service, Veterinary Services, Hyattsville, MD 20782 (U.S.A.)*

ABSTRACT

New, J.C., Jr., Sanders, W.L. and Beal, V.C., Jr., 1990. Enrollment of Tennessee beef herds in the National Animal Health Monitoring System. *Prev. Vet. Med.*, 8: 191-202.

This paper describes a modified area frame approach to selecting beef cow-calf operations randomly which will provide reasonable estimates of population parameters. The methodology of herd selection is probabilistic, is designed to represent the geographic distribution of cattle in the state, and is stratified by herd size. Approximately 72 work days were required and 13 587 miles were travelled to enroll 60 beef herds in Tennessee. The enrollment phase was spread over approximately 3 months and involved 10 veterinarians. The participation refusal rate increased from 23.1% in 1983 to 28.6% in the current study. An important reason for non-participation in the current study was the necessity of handling and bleeding animals.

INTRODUCTION

For many years, the livestock industry, the veterinary profession, education and research institutions, and disease control agencies have operated without meaningful morbidity and mortality data on diseases of animals (Diesch et al., 1974). Infectious disease reporting is strikingly incomplete both in veterinary and human medicine (Schaffner et al., 1971; Ingram et al., 1974; Evans, 1976; Foege et al., 1976).

Many reporting systems for animal diseases have been instituted in this country. Most have been discontinued for a variety of reasons. One important reason is their inability to provide data that are representative of the population of interest (McCallon and Beal, 1982; Beal, 1983). Disease statistics collected by regulatory agencies, meat inspection services, diagnostic laboratories, clinics, and the diagnostic community in general are not in a form that permits valid inferences on the prevalence of disease in entire animal populations (National Research Council, 1974).

0167-5877/90/$03.50

THE NATIONAL ANIMAL HEALTH MONITORING SYSTEM IN TENNESSEE

Round 1

In 1983, a pilot project to develop a national disease reporting system was begun in Tennessee and Ohio. This project was referred to as the National Animal Disease Surveillance Program (NADS). The pilot project dealt with the methodology of collecting disease and economic data from 20 beef, 10 dairy and 10 swine premises across Tennessee.

The sample size ($n=40$) distributed over three different types of premises was not adequate to estimate the prevalence of disease precisely or assess the economic impact of disease on a state-wide basis. Although the sample was randomly selected, the survey design was statistically inefficient.

The main purpose of the pilot project (Round 1) was to identify problems of collecting important disease and economic data, develop forms to collect data and explore the best way to select a representative sample of herds. Data were collected by visiting each premise once a month for 1 year.

Round 2

In 1987, Round 2 of a state-wide data collection project was begun. Monthly visits to premises continued to be an important element of Round 2. During these visits, data were collected on the occurrence of any disease or condition. Data also were collected on monthly inventories, preventive measures taken and the costs of disease/conditions and preventive measures. Premises were monitored for 1 year.

The NAHMS (Round 2) in Tennessee differs from the pilot project in some major ways. First, it was felt that the limited manpower available for such a project should be focused on one type of livestock premises. Beef premises, specifically cow–calf operations, were chosen for monitoring because more Tennesseans are involved in this type of operation than in any other type of livestock operation (Tennessee Crop Reporting Service, 1984; USDA, 1984).

A second difference in Round 2 was the implementation of herd sampling (subsampling). In Round 1, the diagnosis of a disease condition often was based only on producers' opinion. During Round 2 it was decided that blood samples from all enrolled herds would be collected and that willingness to allow the samples to be collected would be one criterion for participation.

The state coordinators of the NAHMS were concerned about refusal rates with this additional requirement. It was felt that some producers might be willing to participate by reporting information during the monthly visits but would not participate if it meant collecting blood samples from their cows. Data were collected on refusals and are discussed later in this paper.

MATERIALS AND METHODS

Sample size

The estimated mean per cent of infected herds was used to determine a realistic sample size. The following formula was used to determine how many herds would be included in Round 2.

$$N = 4\,Pq/L^2$$

where P is the probability of disease, q is the probability of no disease, and L is the allowable error.

Calculations assumed a binomially distributed variable. Published data on the prevalence of bovine virus diarrhea virus, infectious bovine rhinotracheitis virus, parainfluenza 3 virus, and bovine respiratory syncytial virus were used to estimate an average probability of disease. The probabilities of disease on farms were estimated to be at least 0.5 (Pignatelli, 1978; Bittle and Crandell, 1980a, 1980b; Mohanty, 1980; Crandell, 1981; Reggiardo, 1981; Woods, 1981).

With a sample size of 100 herds, a 95% confidence interval around the estimated probability, P, of a disease would give an allowable error of $P \pm 0.1$. One-hundred herds was an unrealistic number based on available manpower. Further discussions and calculations resulted in the decision to select 60 herds. Based on 60 herds, the estimated probability of disease would be $P \pm 0.13$, assuming that the probability that disease exists on a given farm is 0.5.

Sample stratification

Data obtained from the U.S. Department of Agriculture (USDA, 1983) indicated that beef cattle in Tennessee were distributed by herd size as displayed

TABLE 1

Per cent distribution of Tennessee beef cattle by herd size, 1983

Herd size (no. of head)	% of all cattle
1-9	1.2
10-49	47.9
50-99	23.9
100-149	4.7
150-249	15.2
250-499	4.4
500-999	1.8
⩾1000	1.0

Source: USDA (1983).

TABLE 2

Tennessee/NAHMS beef herd size strata, proportion of cattle, proportion and number of herds selected for each stratum, 1987

Strata (herd size)	Proportion of cattle (%)	Proportion of herds selected (%)	No. of herds selected
Stratum 1 (10–49 head)	47.9	48.5	29
Stratum 2 (50–99 head)	23.8	24.1	15
Stratum 3 ($\geqslant$100 head)	27.1	27.4	16

Source: USDA (1983).

in Table 1. Based on this distribution, it was decided that herds of fewer than 10 head (1.2% of all cattle) would be eliminated from the sample. In addition, herds would be collapsed into three strata as shown in Table 2. The percentages given in Table 2 were used to distribute the 60 herds proportionally among the three strata.

Geographic distribution of the sample

In Round 1, the 40 premises to be monitored were distributed equally among 10 data collectors. This was a survey design for convenience, which did not represent the distribution of cattle in the state. It represented, instead, the distribution of APHIS veterinary medical officers (VMOs) in the state. This was not appropriate for Round 2 as the sample was to represent the state-wide distribution of cattle. Consequently, it was decided that the distribution of herds would be based on the cattle population.

Figures from the U.S. Department of Agriculture (USDA, 1983) on cattle population and herd size distribution by county were used to decide where the NAHMS herds should be located. A computer program was written to select randomly counties where herds should be located. Using county beef cattle population figures, a probability of selection was calculated for each county. For example, if County A had twice as many cattle as County B, County A would be twice as likely to be selected as the location of a NAHMS herd as County B. A random list of counties was generated based on these population figures.

The county locations of the 16 herds in stratum 3 ($\geqslant$100 head) were chosen first followed by the 15 herds in stratum 2 (50–99 head) and the 29 herds in stratum 1 (10–49 head). It was decided that no more than two herds of the same size would be allowed in any one county. This was done to avoid clustering of herds which might overrepresent foci of infection.

Each time farms in a new herd size stratum were selected, all counties were

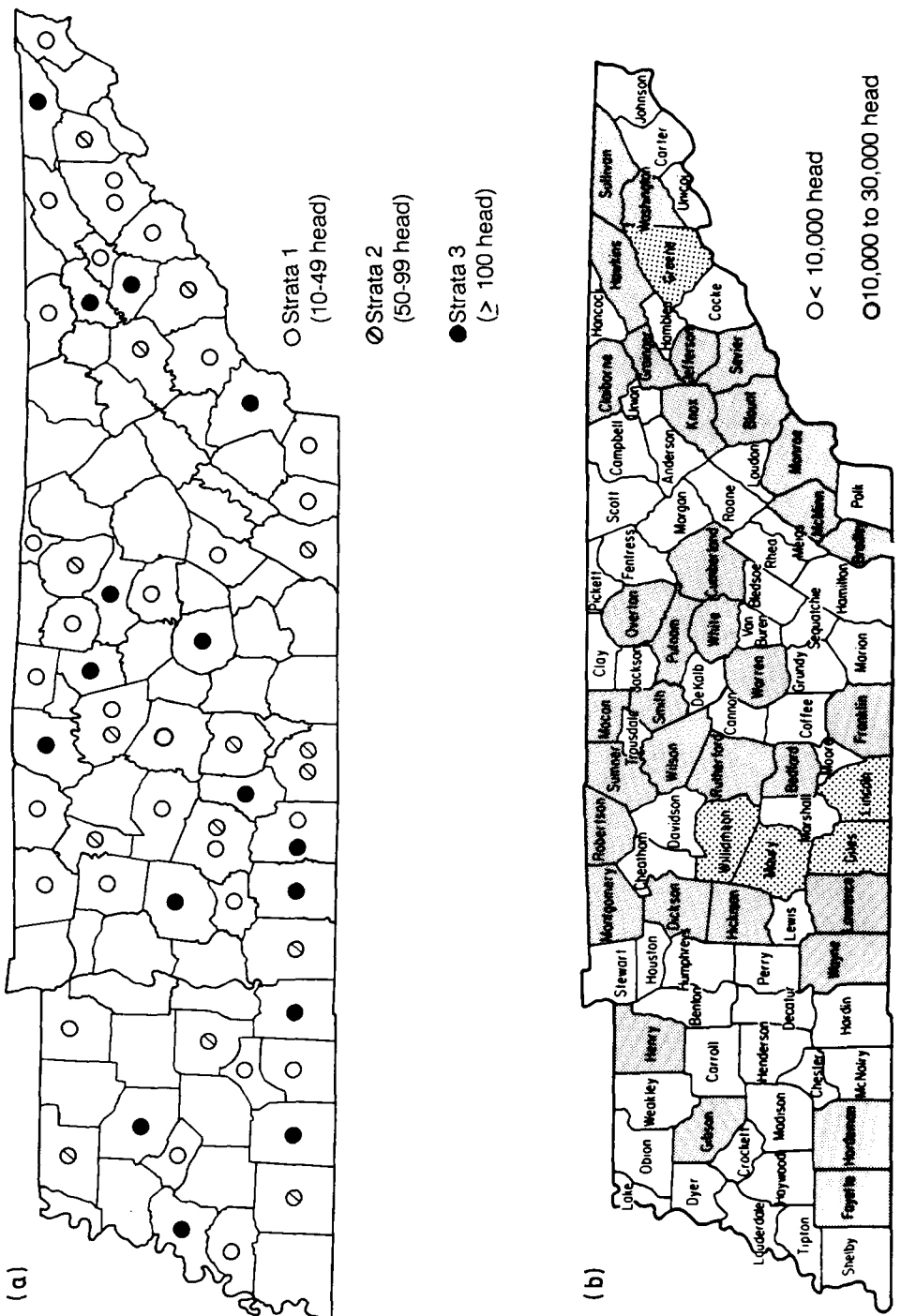

Fig. 1. (a) Location of Tennessee beef herds, by strata, selected for NAHMS, 1987-88. (b) Distribution of Tennessee beef cattle.

replaced as potential locations of herd. Two counties were selected to have two herds of the same size and three counties were selected to have two herds of different herd sizes. All other counties selected were to contain only one herd. Consequently, herds were to be found in 55 different counties. The county location of herds is shown in Fig. 1.

Intraherd sampling

Intraherd sampling (the number of animals to be bled from each herd) was designed to maintain a constant confidence interval around the estimated prevalence of disease regardless of herd size. The correction for a finite sample (Snedecor and Cochran, 1968) was used to achieve a constant confidence interval (95% confidence interval, $P \pm 0.1$). Consequently, as herd size increased, the percentage of the herd bled decreased.

Herd selection

Random selection from list frames was the method of choice for the convenience sample drawn for Round 1. Data collectors quickly found that there were no lists of beef producers that were complete and accurate enough for use in random selection. The Tennessee and Ohio experience during the pilot phase of the program led national staff to explore, in other states, other methods of finding herds in a random way that would represent state-wide populations (Beal, 1986).

Three techniques have been used to select randomly herds for participation in the NAHMS. The list frame method uses existing or generated lists of livestock producers to select randomly herds for participation. The area frame method can use random paths (or walks) drawn on a road map. The first herd encountered along the path that meets the sample criteria (e.g. herd size) is selected. The multiple frame method uses elements of both list and area frames. In areas where Statistical Reporting Service (SRS, now called the National Agriculture Statistics Service) records indicate that there are a small number of herds, a list of herds is generated and used to select herds randomly. Where large numbers of potentially eligible herds are expected, area segments are constructed which are equal to a density of one herd (Beal, 1985).

The list frame method is limited and inadequate in certain settings. Complete herd lists for list frame selection are rarely available because they are difficult and expensive to construct, maintain, and update (Beal, 1985; Gardner et al., 1985; Danaye-Elmi et al., 1986). In addition, list frames tend to under-represent small herds (Beal, 1985; Gardner et al., 1985).

List frames for Tennessee beef cow–calf premises were found to be unacceptable during Round 1. Existing lists were found to contain many producers' names who no longer had cattle and the lists had not been updated recently

enough to include new producers (Beal, 1985). In California, 46% of beef producer names from a SRS list were not valid. Many had no cattle or only dairy cows (Danaye-Elmi et al., 1986). The bias of list frames toward larger herds cannot be ignored, as a large number of Tennessee beef producers have small herds (Table 1), and in at least one study small beef herds reported proportionally more disease than medium and large ones (Danaye-Elmi et al., 1986).

The area frame method of herd selection also has limitations. The random walk is unsatisfactory because it requires extensive travel and does not take into account varying densities within a county (Beal, 1985). However, a modification of the area frame method was used to select beef herds in Tennessee for Round 2 of NAHMS.

Once herd locations were assigned randomly by herd size to counties, a method to find appropriate herds randomly within a county was developed. The number of herds in a particular county (USDA, 1983) was divided into the area (square miles) of that county (University of Tennessee, 1985) to determine the density of herds. A grid was then drawn on a map of the county, with cells approximately equal to the estimated density of herds. For example, if it was estimated that there was one beef herd of the appropriate size in the county per square mile, the grid on the map of that county contained cells with areas of 1 square mile. The smallest cells were 0.5 square miles and there were 14 counties with cells of this size. The largest cell was 30 square miles, which occurred in one county.

Once the grids were drawn, the rows and columns were numbered. A table of random numbers was used to select cells by randomly selecting a row and column number. Cells chosen in this manner were listed in order of selection on a NAHMS Herd Location Plan. The plan, together with the county map with the grid, was then given to the data collector.

The plan called for the data collector to proceed to the first cell listed and explore it for an eligible herd. In counties with cells of 1 square mile or more, a subplan was provided to try to ensure random selection of herds. A randomly selected point (usually an intersection) was indicated within the cell. From this starting point, the data collector was to flip a coin to determine direction of travel. At new intersections, a coin was again used to determine direction.

Data collectors tried to enroll the first herd found that qualified. If the herd owner chose not to participate, the data collector continued to explore the cell until all possibilities were exhausted. If no herd was enrolled in the first cell, the data collector would proceed to the second cell and repeat the process. If a herd was not enrolled in a cell, reasons were reported by the data collectors. "No cattle" and "no eligible herds" were common reasons for not enrolling herds in particular cells.

The location plan for each county included at least eight randomly selected cells. If all cells were exhausted without enrolling a herd, additional cells were selected using the method previously described. This happened on three oc-

casions. In the two counties where two herds of the same size were to be found, only one herd per cell was allowed. In the three counties where two herds of different herd size were to be found, a different location plan was developed for each herd size.

Approximately one-third of the total number of herds was to be enrolled each month for three consecutive months. Staggered enrollment was intended to reduce the work-load, which was expected to be very heavy during the enrollment phase of the project. Fifty-seven of the 60 herds (95%) were enrolled during the period July–September 1987. Additional herds (one each), were enrolled in June, November and December, 1987.

Information was collected during the enrollment phase of the project to document the time spent and miles traveled to enroll herds. Additional data were collected on the number of cells visited, reasons for not enrolling a herd in each cell visited and number of refusals. Summaries of these data follow.

RESULTS

Geographic distribution of sample herds by cattle population

Figure 1 illustrates the location of the 60 NAHMS herds by strata and the distribution of beef cattle in the state. Twenty NAHMS herds (33.3%) were located in counties with fewer than 10 000 head of beef cattle. Thirty-one NAHMS herds (51.7%) were located in counties with 10 000–30 000 head and nine (15%) were located in counties with over 30 000 head.

TABLE 3

Average miles traveled, time spent and number of cells visited to enroll NAHMS beef herds in Tennessee, 1987

Strata (herd size)	No. of herds required	Average distance traveled (miles)	Average time spent (h)	Average no. of cells visited
Stratum 1 (10–49 head)	29	216.4	8.7	2.9
Stratum 2 (50–99 head)	15	197.3	8.7	2.7
Stratum 3 ($\geq$ 100 head)	16	272.1	12.1	3.6
All strata	60	226.5	9.6	3.1

TABLE 4

Frequency and per cent of Tennessee/NAHMS beef herds enrolled by number of cells visited, 1987

No. of cells visited	No. of herds enrolled	%
1[a]	17	28.3
2	17	28.3
3	7	11.7
4	8	13.3
5-7	6	10.0
8-10	4	6.7
>10	1	1.7

[a]Seventeen herds were enrolled in the first area visited as prescribed by the NAHMS Herd Location Plan.

Miles traveled and time spent

A total of 13 587 miles were traveled and 578 h (approximately 72, 8-h work days) were spent by 10 veterinarians to enroll 60 beef herds. Table 3 shows the average miles traveled and time spent by herd size.

Information was also collected on the number of cells in each county that had to be visited to enroll each herd. Table 4 shows the frequency of enrolling an eligible herd by number of cells visited.

Refusal rate and reasons for refusal

During the enrollment phase, 24 producers (28.6%) refused to participate even though they were eligible. There was a refusal rate of 29.3% for stratum 1 herds, 31.8% for stratum 2 herds, and 23.8% for stratum 3 herds.

A form was left with each of these producers which asked them to record reasons for not participating. Stamped, addressed envelopes were provided with each form to maintain anonymity and encourage the return of forms. Thirteen eligible producers (54.1%) who did not enroll in the program returned forms.

The form consisted of a short letter acknowledging the owner's choice not to participate. The letter asked for the owner's anonymous response(s) regarding reasons for non-participation. Owners were to return the bottom half of the letter which consisted of five specific reasons for non-participation which could be checked. The choices were: (1) no facilities to corral or handle cattle for bleeding; (2) do not want to be bothered; (3) do not want my animals bled; (4) do not want to know if I have diseases in my herd; (5) if I have disease in my herd, I do not want anyone else to know.

Half of the form was left blank with instructions for the owner to add other reasons or comments if desired. Six of the 13 forms returned contained specific comments instead of or in addition to one or more of the checked options available on the form.

Seven of the 13 owners indicated that the aspect of handling and/or bleeding cattle was a reason for non-participation. Lack of handling facilities was a major reason reported by three owners. Seven of the 13 owners indicated that they did not want to be bothered or did not have time to participate. Ill health on the part of two owners was a contributing reason for non-participation. Six owners gave more than one reason for non-participation.

Refusal rates and reasons for refusal from other states involved in the NAHMS are not consistently reported. In Iowa's Round 1, 20% of beef and swine producers contacted refused to participate. No reasons for refusal were reported (Owen, 1986). In Michigan's Round 1, 10.7% of dairies contacted declined to participate. Reasons for non-participation included concern about the amount of work involved, general lack of interest, and family illness (Kaneene and Hurd, 1987). Sixteen dairies were included in Ohio's Round 2. To enroll these dairies, at least 20 dairies were contacted, to allow for a minimum refusal rate of 20% (four out of 20 dairies contacted). Reasons for refusal included "going out of business" and "too much trouble" (Miller, 1987). The rate of refusal of beef producers during Tennessee's Round 1 was 23.1%. Data on the reasons for non-participation during Round 1 were not collected.

In other states involved in the NAHMS, subsampling (the collection of blood and/or other specimens from a portion of participating herds) was conducted. It is not clear from reports for other states whether willingness to allow the collection of samples was an initial requirement of enrollment (Owen, 1986; Kaneene and Hurd, 1987; Miller, 1987).

CONCLUSIONS

Enrolling herds has been the most time-consuming part of this project to date. To ensure the adequacy of the sample, this phase will probably continue to be very time consuming in future rounds. It would not have been possible to enroll this many herds in a 1-month period. To do so would have committed at least a quarter of a veterinarian's time during the enrollment month. Staggered enrollment probably will continue to be necessary.

Documentation of diagnoses on a herd basis must be continued. The requirement of collection of blood samples may have had an effect on the refusal rate. However, the refusal rate between Round 1 and Round 2 increased by only 5.5% and no blood samples were collected in Round 1. Handling of animals may be more of a problem in beef cow–calf operations than in other types of livestock operations because of a general lack of cattle-handling facilities.

The NAHMS has evolved over the last few years. The question of how best

to select herds to represent state, regional and eventually national populations is still open to debate. In the case of beef cow–calf herds, list frames have not proved reliable. A method of randomly finding herds such as described here may represent the best approach currently available. Care must be taken so that sample herds represent the larger populations in important features such as geographic distribution of animals and herd size.

ACKNOWLEDGEMENTS

We express our appreciation to the state and federal veterinarians involved in this project. In addition, we thank the numerous private veterinary practitioners and county agriculture extension personnel who were very helpful during the enrollment phase of this project. The NAHMS Round 2 was supported by USDA–APHIS–VS Cooperative Agreement No. 12-16-93-264, The College of Veterinary Medicine Center of Excellence, and the University of Tennessee Departments of Rural and Environmental Practice.

REFERENCES

Beal, V.C., 1983. Perspectives on animal disease surveillance. Proc. U.S. Anim. Health Assoc., 87: 359–385.

Beal, V.C., 1985. The animal disease survey sampling and estimation problem. Proc. U.S. Anim. Health Assoc., 89: 92–111.

Beal, V.C., 1986. Regulatory statistics 2A: Considerations about animal disease surveillance. USDA, APHIS, Veterinary Services, 11.8–11.13.

Bittle, J.L. and Crandell, R.A., 1980a. Bovine virus diarrhea. In: H.E. Amstutz (Editor), Bovine Medicine and Surgery. American Veterinary Publications, Santa Barbara, CA, pp. 122–127.

Bittle, J.L. and Crandell, R.A., 1980b. Infectious bovine rhinotracheitis. In: H.E. Amstutz (Editor), Bovine Medicine and Surgery. American Veterinary Publications, Santa Barbara, CA, pp. 106–113.

Crandell, R.A., 1981. Infectious bovine rhinotracheitis. In: J.L. Howard (Editor), Current Veterinary Therapy: Food Animal Practice. W.B. Saunders, Philadelphia, PA, pp. 453–545.

Danaye-Elmi, C., Gardner, I.A., Hird, D.W. and Utterback, W.W., 1986. National Animal Health Monitoring System evaluation of list frames for disease surveillance sampling of California beef cattle and comparison of NAHMS pilot project with retrospective interview data. Proc. U.S. Anim. Health Assoc., 90: 73–85.

Diesch, S.L., Martin, F.B., Johnson, D.W. and Christensen, L.T., 1974. The Minnesota reporting system for food producing animals. Proc. U.S. Anim. Health Assoc., 78: 3–27.

Evans, A.S., 1976. Surveillance and seroepidemiology. In: A.S. Evans (Editor), Infections of Humans: Epidemiology and Control. Plenum Medical Book Co., New York, pp. 33–52.

Foege, W.H., Hogan, R.C. and Newton, L.H., 1976. Surveillance projects for selected diseases. Int. J. Epidemiol., 5: 29–37.

Gardner, I., Hird, D.W. and Heron, B.R., 1985. National Animal Disease Detection System evaluation of list frames for disease surveillance of California swine. Proc. U.S. Anim. Health Assoc., 89: 79–91.

Ingram, D.G., Mitchell, W.R., Martin, S.W. (Editors), 1974. Animal Disease Monitoring. Charles C. Thomas, Springfield, IL, 228 pp.

Kaneene, J.B. and Hurd, H.S., 1987. National Animal Health Monitoring System Round 1 - Final report. Michigan State University, College of Veterinary Medicine, 88 pp.

McCallon, W.R. and Beal, V.C., 1982. Historical aspects of animal disease reporting and the development of a national animal disease surveillance system. Proc. U.S. Anim. Health Assoc., 86: 341-349.

Miller, G., 1987. Evaluation of economic and epidemiologic data from the National Animal Disease Detection System (NADDS): Final report of Round 2. The Ohio State University, College of Veterinary Medicine, 184 pp.

Mohanty, S.B., 1980. Herpes-, rhino-, and syncytial virus infections. In: H.E. Amstutz (Editor), Bovine Medicine and Surgery. American Veterinary Publications, Santa Barbara, CA, pp. 113-120.

National Research Council, 1974. A Nationwide System for Animal Health Surveillance. Committee on Animal Health. National Research Council, Washington, DC, 56 pp.

Owen, W.J., 1986. Iowa Round 1: Technical report, August 1984-October 1985. Iowa State University, College of Veterinary Medicine.

Pignatelli, P., 1978. Respiratory disease and the incidence of pulmonary mycoplasmosis in intensively-reared calves in Italy. In: W.B. Martin (Editor), Respiratory Diseases in Cattle. Martinus Nijhoff, Norwell, MA, pp. 284-294.

Reggiardo, C., 1981. Bovine viral diarrhea-mucosal disease. In: J.L. Howard (Editor), Current Veterinary Therapy: Food Animal Practice. W.B. Saunders, Philadelphia, PA, pp. 586-590.

Schaffner, W., Scott, H.D., Rosenstein, B.J. and Byrne, E.B., 1971. Innovative communicable disease reporting: The Rhode Island experiment. HSMHA Health Reports, 85: 431-436.

Snedecor, G.W. and Cochran, W.G., 1968. Statistical Methods. Iowa State University Press, Ames, IA, pp. 517-518.

Tennessee Crop Reporting Service, 1984. Tennessee Agricultural Statistics 1984, Annual Bulletin. Tennessee Crop Reporting Service, Bull. T-21.

USDA, 1983. Computer printout from list frame data of the National Agricultural Statistics Service (unpublished). National Agricultural Statistics Service, Washington, DC.

USDA, 1984. Agricultural Statistics 1984. U.S. Department of Agriculture, U.S. Government Printing Office, Washington, DC, pp. 261-273.

University of Tennessee, 1985. Tennessee Statistical Abstract 1985-86. The University of Tennessee, Knoxville Center for Business and Economic Research.

Woods, G.T., 1981. Parainfluenza 3 virus. In: J.L. Howard (Editor), Current Veterinary Therapy: Food Animal Practice. W.B. Saunders, Philadelphia, PA, pp. 546-549.